X-326-62-22

FLIGHT ACCEPTANCE ENVIRONMENTAL TEST PROGRAM OF THE TIROS D METEOROLOGICAL SATELLITE

PREPARED BY
TEST AND EVALUATION DIVISION
OFFICE OF TECHNICAL SERVICES

(NASA-TM-X-66801) FLIGHT ACCEPTANCE ENVIRONMENTAL TEST PROGRAM OF THE TIROS D METEOROLOGICAL SATELLITE (NASA) 24 p

N75-73959

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FLIGHT ACCEPTANCE

ENVIRONMENTAL TEST PROGRAM

OF THE

TIROS D METEOROLOGICAL SATELLITE

April 20, 1962

Prepared by:

Edward D. Alvord, Jr.

Edward D. Alvord, Jr.
Applications Spacecraft
Test Programs Section

Reviewed by:

K. R. Mercy

K. R. Mercy
Head, Applications Spacecraft
Test Programs Section

L. Dillwyn Eckard, Jr.

L. Dillwyn Eckard, Jr.
Head, System Evaluation Branch

Approved by:

J. H. Boeckel for

John C. New
Chief, Test and Evaluation Division

TEST PROGRAM STATUS

This is the final report on the TIROS D Spacecraft Environmental Test Program. This satellite is now in orbit and is designated Tiros IV.

AUTHORIZATION

GSFC Job Order No. 622-M-61-01

Test and Evaluation Division Nos. 330-338

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by

Edward D. Alvord, Jr.
Goddard Space Flight Center

SUMMARY

The Tiros Project has as its missions the observation of atmospheric conditions and transmission of this data for use by meteorologists. The satellite was designed for launch by a Thor-Delta vehicle.

Environmental testing of Tiros D was performed by the RCA Space Center, Princeton, New Jersey. The test program was monitored and witnessed by a representative of the Test and Evaluation Division of GSFC/NASA.

The primary objective of the test program was to locate any latent defects in material and workmanship, thereby providing assurance that no degradation had occurred in manufacturing, inspection, or handling, and thus giving confidence that no spacecraft malfunction would be probable in actual operation.

This report presents the Flight Acceptance Tests which were the final phase of the Environmental Test Program, completed in accordance with the test specifications and the test plan for Tiros D.

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1. INTRODUCTION

The mission of Project Tiros is to obtain, by means of satellites, meteorological data that will assist scientists throughout the world in their search for a better understanding of the factors that control the world's weather.

The primary objective of the Tiros Program is to launch into orbit a satellite capable of observing atmospheric conditions with television cameras and radiation sensors and transmitting this data for exploitation by meteorologists. The secondary objectives are to monitor the thermal conditions in the spacecraft, demonstrate the performance of the payload subsystems, and determine the dynamic stability of the spacecraft.

The Environmental Test Program was designed to produce a high level of confidence in the ability of the Tiros D spacecraft to successfully withstand the environments expected during handling, shipment, launch, and in orbital flight.

This report presents factual data on major events occurring during the Flight Acceptance Test program for Tiros D. The report also contains the conclusions reached as a result of the program and recommendations intended to initiate improvements in future spacecraft and environmental test programs.

The Tiros D spacecraft (RCA Serial F-1) had been the flight model for the original Tiros launch (Tiros I) until replaced by the back-up after premature firing of the

despin squib on the pad. Subsequently, the Tiros D spacecraft had served as backup for the Tiros II and Tiros III launches before being launched itself on February 8, 1962 from Cape Canaveral, following the Flight Acceptance Tests described herein.

The Delta launch vehicle placed the spacecraft in an approximately circular orbit ranging from 441 nautical miles at perigee to 525 nautical miles at apogee. The orbiting spacecraft was renamed TIROS IV.

At the date of this report all instrumentation was operating in a satisfactory manner.

2. BACKGROUND AND HISTORY

High reliability is a prime requirement for any effective space program. This requirement arises partially from the high cost of the advanced and novel instruments characteristic of space research and partially from the high cost of launch vehicle and operations. In addition, certain space operations, such as the meteorological missions, must be successfully accomplished in a specific time period to fulfill requirements. Thus, assurance of success must be increased by every possible means. An effective technique for obtaining such increased assurance is the application to the spacecraft in the laboratory of controlled environments which simulate, insofar as practical, the conditions actually to be encountered by the spacecraft.

A continuous long-term program for upgrading environmental testing is in operation, based on thorough evaluation of previous spacecraft test programs and comparison of orbital performance data against results obtained during testing.

Eventually, this program is expected to lead to test criteria and procedures which will increase confidence in the ability of the spacecraft to survive the pre-launch and launch environments and to operate within design limits for the specified orbital lifetime.

Based on this philosophy, the document Specifications for the Tiros Meteorological Satellite System, dated September, 1961, was prepared by the Aeronomy and Meteorological Division of GSFC which contained the test levels, test sequence, and monitoring procedures as coordinated with the Test and Evaluation Division of GSFC.

The test levels selected had the purpose of assuring that odds against the satellite being disabled by the rigors of launch or flight would be maximized. Because of the scarcity in number of models for normal statistical sampling, this assurance was established by subjecting a few prototype models to much greater rigors of environment than expected during launch and flight. Then an additional but less rigorous series of Acceptance Tests were conducted on the Flight models as described below.

Testing of the Tiros D flight model (RCA Serial F-1) was begun November 16, 1961 and continued without any major interruptions until January 17, 1962, when the spacecraft was accepted as qualified and ready for launch. The testing was performed by the RCA Space Center, Princeton, New Jersey.

3. TEST OBJECTIVES

The Tiros D Environmental Test Program objectives were:

(1) To locate latent defects in material and workmanship, thereby providing assurance that none of the essential characteristics of the spacecraft design had been degraded during manufacturing and the accompanying inspection and handling.

(2) To demonstrate the compatability of all parts of the system under simulated launch and orbital environments.

(3) By the evaluation of test procedures, tests, and test results, with respect to spacecraft performance, to generate knowledge and data

for qualitatively assessing the reliability of the spacecraft system and to provide a basis for improving future spacecraft designs and test programs.

Specifically, this program was designed to provide, within the limitations of the environmental test laboratory and the project schedule, reasonable assurance that the environmental stresses associated with payload handling, shipment, launch, and orbit could be sustained.

4. TEST PLAN

BACKGROUND

Environmental exposures should be applied according to a well-defined test program which gives proper attention to test levels, sequence of application, and detailed monitoring procedures. Tests improperly planned or conducted may lead to a false sense of reliability attainment.

The test plan was sufficiently comprehensive to provide those concerned with the evaluation program a basic knowledge of the mission requirements, the spacecraft and its functions, the method of testing planned, and the proposed test schedule. The test plan included methods and procedures by which the proper performance of the spacecraft before, during, and after exposure to environmental testing could be determined.

The Tiros D test plan covered three phases of testing.

(1) Prototype testing of new components.
(2) Flight acceptance testing of new components.
(3) Flight acceptance testing of the complete Tiros D satellite.

The first two phases were performed by the prime contractor, RCA. The third phase, performed by RCA at its facilities, was monitored and witnessed by representatives of the Test and Evaluation Division and is described in this report.

TEST DESCRIPTION

The equipment used at RCA facilities consisted of a Ling-Calidyne, 2,268 kg (5,000 lb) Vibration Exciter on loan from Goddard Space Flight Center, a Consolidated Vacuum Corp., 1.2 m x 1.5 m (4' x 5') Thermal-vacuum Chamber, and balance equipment designed and fabricated by RCA.

The environmental tests employed were intended to simulate the various environmental conditions expected during pre-flight, launch and orbit as described in the following paragraphs.

Balance

Static and dynamic balancing of the spacecraft was specified to ensure spin stability of the spacecraft in orbit. Although not an environmental test, this procedure is a necessary prerequisite for a Flight Spacecraft.

Vibration Test

Vibratory excitation of the spacecraft arises from shipment and rocket motor burning (primarily the third stage), as well as from acoustic and aerodynamic sources.

The random excitation tests were conducted primarily to simulate maximum dynamic pressure in flight and acoustical vibrations.

Random tests in three orthogonal directions--one parallel to the spacecraft spin axis and two along arbitrarily selected, mutually perpendicular transverse axes--were specified.

The sinusoidal vibration tests, designed to simulate shipment and induced vibrations, have been waived on recent Tiros spacecraft since the rigors induced by the random excitation mentioned above exceed those produced by sinusoidal vibration and because sinusoidal tests are essentially diagnostic in nature, and thus were used during the engineering design and design qualification of prototype phases of the Tiros Program.

Thermal-vacuum Test

This series of tests was intended to verify the satisfactory operation of the spacecraft system under the combined environments of temperature and high vacuum. Tests at +50°C and 0°C, combined with a vacuum of 5 x 10^{-5}mm Hg, were specified.

5. TEST RESULTS

Although no catastrophic failures in operation or structure were revealed by the Flight Acceptance Tests, several malfunctions and a structural failure occurred.

Degradation of the battery pack performance below acceptable standards was observed but could not be related directly to any part of the environmental test program. This discrepancy became evident when the beacon transmitters were removed for re-work and requalification after the initial thermal-vacuum exposure. It was decided to replace the degraded pack with the back-up before the next thermal-vacuum test and proceed with the test program.*

---

* On December 22, 1961, the battery pack on "D" spacecraft was given a capacity test by applying charge and discharge cycles. The data revealed that this pack had degraded below the acceptable 3.4 ampere hour discharge capacity. This pack had been installed on F-1 after the original pack failed during the thermal-vacuum tests performed in October. Previous measurements in June and September showed a capacity of 3.7 to 4.1 ampere hours. Past history has shown that a large number of battery packs have degraded from no apparent cause. RCA discussions with Sonotone and reports by STL (#2303-0003-RU-000 "Final Report: Study of Sonotone Corporation Nickel-Cadmium Size F Battery Cells") indicate that these nickel-cadmium paper-base separater cells should not be operated above 30 to 35°C. The Tiros test program requires the spacecraft with batteries to be subjected to 50°C for 3 days minimum in addition to the unit tests. The performance of TIROS II spacecraft, now in orbit for over one year, indicates actual battery temperatures to be around 10 to 15°C except for 4 days in a 100% sun orbit when temperatures as high as 32°C were experienced, as well as 2 days at 24°C.

Among failures directly related to the Acceptance Tests were breakdowns of the beacon transmitters, one of which was finally replaced by a qualified spare. The structural failure consisted of cracks in the base plate ribs which occurred during random vibration. Malfunctions in the TV system included loss of belt drive in one of the tape recorders and a broken wire on one of the camera shutters. Another malfunction was absence of cut-off of the tape pulse in the IR system. These and additional malfunctions which occurred are described below under the applicable tests.

Acceptance Tests of the Tiros D were initiated on November 16, 1961 and continued through January 16, 1962. During this 62 day period, 32 days were consumed by actual tests or set up operations (3 days, balance; 13 days, vibration; and 16 days, thermal-vacuum.)

Enumerated below are the test results, arranged by type of test. See Appendix A for log of test activity.

INITIAL BALANCE

Initial balance operations were concluded with a total of 2.83 kgs (6.25 lbs) added to the spacecraft. During this operation a loose nut was found in the spacecraft and was removed.

INITIAL VIBRATION

During the pre-vibration checkout, Tape Recorder Number 1 drive was lost. New belts were installed on both tape recorders. Tape transports on both tape recorders were cleaned at this time. While under random vibration in the thrust axis, a beacon transmitter failed. Subsequent vibration of this beacon transmitter unit was unable to reproduce this failure. However, in light of this failure a spare beacon transmitter was installed in the spacecraft. Subsequent to this random vibration test, a loose balance weight was found. This loose weight had damaged the angle supports in the structure. This damage was repaired and, in addition, the supports were reinforced. After completion

of these repairs and during an attempt to equalize the vibration machine, a structural failure was discovered. Ten fractures in the primary structure, supporting the base plate, were discovered. Tests were terminated pending repairs to the structure.

BALANCE

After completion of repairs to the structure of the spacecraft, balancing operations were again conducted. A total of 3.17 kgs (6.99 lbs) was added to the spacecraft.

VIBRATION

Prior to the vibration test, the wire which actuates the shutter of TV Camera Number 2 was found to be broken and was replaced. No failures were encountered during the ensuing vibration tests. However, difficulties with Dr. Suomi's experiment were experienced. Interference with IR data was traced to this source. After completion of the vibration tests, one hemisphere on this experiment was replaced. Some difficulties were also experienced in the operation of the vibration equipment, delaying completion of these tests.

During the +50°C hot test, difficulties were experienced because of a malfunction of the radiometer and late in the course of the hot test, one beacon transmitter lost power. This loss was attributed to unresolved design problems. It was decided at this time to make changes in the beacon transmitters, check out the IR package and replace the wide field radiometer. After these changes were accomplished and the redesigned transmitters were qualified, the thermal-vacuum tests were resumed. During the +50°C hot test, a power loss from one beacon transmitter was noted. Subsequent checks revealed the source of the difficulty to be a faulty cable connector which was replaced. During the final checkout, prior to resuming the thermal-vacuum test, it was noted that there was no "end-of-tape" pulse in the IR system. The difficulty was traced to the IRC board which was replaced. Further investigation of the failure revealed a defective transistor.

A complete 8 day hot-cold thermal-vacuum test sequence was then completed without further discrepancies.

During subsequent IR and TV calibration a beacon transmitter failure was caused by an inadvertent grounding of the test leads, causing a short circuit. This beacon was replaced with a qualified spare.

FINAL VIBRATION

Following the thermal-vacuum tests, the spacecraft was subjected to a series of reduced frequency range random vibration tests. No failures were encountered during the course of these tests. Once again, however, several days delay in completion of these tests was caused by extensive malfunctions of the laboratory vibration equipment.

FINAL BALANCE

Final balance, moment of inertia, and center of gravity determinations were conducted prior to shipment of the spacecraft to Cape Canaveral, Florida with the following results:

Additional weight added	127.6 grams (4.5 oz)
Residual unbalance	
Camera plane	2.1×10^5 dyne-cm (3 oz-in.)
Top plane	3.5×10^4 dyne-cm (½ oz-in.)
Total weight of spacecraft	129.9 kg (286.31 lbs)
Center of Gravity above separation plane on spin axis	24.9 cm (9.8 in.)

Moment of Inertia about spin axis	1.7×10^8 gram-cm^2 (154.8 lbs - in.sec^2)
About other axes	1.2×10^8 gram-cm^2 (109 lbs-in.sec^2)
Run out	.0889 cm (0.035 in.)

At the conclusion of these operations the Tiros D spacecraft was accepted as qualified for flight.

6. CONCLUSIONS AND RECOMMENDATIONS:

(1) The flight model of the TIROS D spacecraft was subjected to the series of tests as described in this report. Based on a review of the test results and spacecraft history, Tiros D was accepted by the NASA project group for shipment to Cape Canaveral. The subsequent launch and performance of Tiros D supports the effectiveness of the test program.

(2) The Acceptance Tests could have been completed at least several days earlier if breakdowns in the vibration equipment at the RCA Space Center, Princeton, New Jersey, had not occurred. Because of this situation, it was suggested that additional emphasis be placed on preventive maintenance. Subsequently, schedules for maintenance of this equipment were established, and performance has reportedly been improved.

(3) The present RCA equipment for lateral plane vibration is not satisfactory because it tends to vibrate in an arc instead of plane. Therefore it is recommended that a slippery table or hydrostatic bearing table be used for lateral plane vibration of future TIROS spacecraft.

ILLUSTRATION

Figure No.

Tiros D Spacecraft..... 1

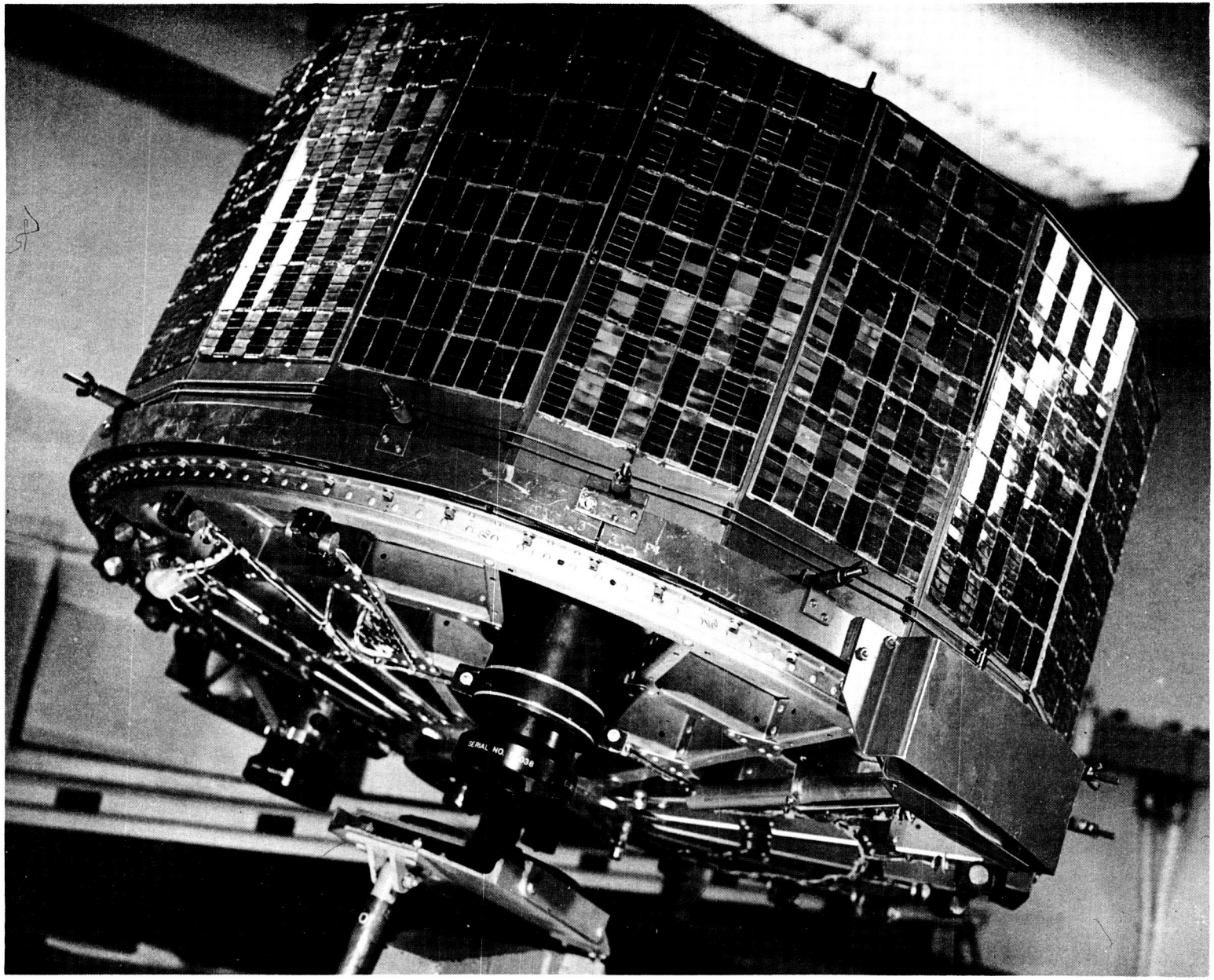

Figure 1. TIROS D Spacecraft

APPENDIX A
DESCRIPTION OF SPACECRAFT

APPENDIX A: DESCRIPTION OF SPACECRAFT

The Tiros D spacecraft is an 18-sided polygon, 22.9cm (19 in.) high and 106.7cm (42 in.) in diameter, weighing 129.9kg (286 lbs, 5 oz). The power supply consists of nickel-cadmium batteries that are rechargeable by solar cells. The spacecraft contains two television systems, each consisting of an independent set of components. Two wide angle cameras provide coverage for viewing cloud formations. A tape recorder is provided for each system which will store a sequence of 32 television pictures for read-out when commanded. Radiation sensors continuously record radiation data on tape for readout when commanded. The interrogation command activates two command transmitters which relay the data. Two beacon transmitters are provided to aid in tracking. These beacon signals are modulated on command to give satellite environmental and attitude information.

APPENDIX B
LOG OF TEST ACTIVITY

APPENDIX B: LOG OF TEST ACTIVITY

Date	Test	Remarks
Nov. 16, 1961	Balance	Weight added 2.8 kg (6 lb, 4 oz) Loose nut found and removed.
Nov. 22, 1961	Checkout prior to vibration	TV tape recorder No. 1 lost its belt drive. Both recorders had their tape transports cleaned and new belts installed.
Nov. 24, 1961	Random vibration	Thrust axis - 20 to 400 cycles/sec .025 g^2/cps, 2 minutes.
		Thrust axis - 400 to 1400 cycles/sec .025 g^2/cps, 30 seconds.
		Thrust axis - 1400 to 2000 cycles/sec .025 g^2/cps, 30 seconds. High frequency beacon transmitter found to have failed during this exposure.
Nov. 25, 1961	Sine vibration	Resonance survey - Sine input of 1 g (0-to-peak) found a maximum q of 16 at 375 cycles/sec. on the beacon transmitter. After completion of test, the beacon transmitter recovered and no reason for the failure was found. A balance weight was found to have torn loose from its mounting. This was repaired.
Nov. 25, 1961	Random vibration	Thrust axis equalization - Found a structural failure consisting of cracks in the base plate ribs. The structure was repaired.

Date	Test	Remarks
Dec. 3, 1961	Balance	To correct imbalance in base (camera plane) of 10 x 10^8 dyne-cm (40,000 gram-in.) at 119° 39', added 1050 grams at 110° and 980 grams at 130°. For imbalance in top plane of 5.3 x 10^8 dyne-cm (21,300 gram-in.) at 204° 3', added 1143 grams at 204°.
Dec. 5, 1961	Random vibration	Prior to vibration, a broken wire was repaired on No. 2 TV camera shutter. Thrust axis - 400 to 2000 cycles/sec .025 g^2/cps, 30 seconds. Thrust axis - 20 to 400 cycles/sec .025 g^2/cps, 2 minutes. No failures.
Dec. 6, 1961	Random vibration	First lateral, 20 to 630 cycles/sec .025 g^2/cps, 2 minutes. Second lateral, 20 to 630 cycles/sec .025 g^2/cps, 2 minutes. No failures.
Dec. 7, 1961	Random vibration	First lateral, 630 to 1000 cycles/sec .025 g^2/cps, 30 seconds. Second Lateral, 630 to 1000 cycles/sec .025 g^2/cps, 30 seconds. No failures.
Dec. 8, 1961	Random vibration	First lateral, 1000 to 2000 cycles/sec .025 g^2/cps, 30 seconds. Second lateral, 1000 to 2000 cycles/sec .025 g^2/cps, 30 seconds. No failures.

Date	Test	Remarks
Dec. 9, 1961	Thermal-Vacuum	After three days at 50°C, a beacon transmitter failed. The problem was investigated, and both transmitters were re-worked.
Dec. 26, 1961	Thermal-Vacuum	After reaching vacuum and going to 50°C, more beacon transmitter trouble was found. A bad cable was replaced, repairing the trouble.
Dec. 27, 1961	Thermal-Vacuum	During the final checkout prior to pump-down, it was noticed that there was no cut-off of tape pulse in the IR system. An IRC board was replaced and testing resumed. Investigation disclosed that a bad transistor was the cause of the failure on the IRC board. Eight days of thermal-vacuum testing was completed successfully. During IR and TV calibrations, a beacon transmitter failed. Evidence indicated that the failure was caused by shorting during the testing. The beacon transmitter was replaced with a qualified spare.
Jan. 8, 1962	Random vibration	Vibration equipment trouble prevented testing.
Jan. 9, 1962	Random vibration	Thrust axis-30 to 530 cycles/sec .025 g^2/cps, 2 minutes. No failures.

Date	Test	Remarks
Jan. 10, 1962	Random vibration	First lateral, 20 to 500 cycles/sec .025 g^2/cps 2 minutes. Second lateral, 20 to 540 cycles/sec .025 g^2/cps 2 minutes. No failures.
Jan. 15, 1962	Final balance	Base (Camera plane), 94 grams at 330°. Top plane, 16.8 grams at 207° 16.8 grams at 198° radius 41.77 cm (20.38 inches). Note: After above adjustment, the final balance was within the specification requirement of 4.2×10^5 dyne-cm (6 in.-oz); (Test equipment can determine 3.5×10^4 dyne-cm (.5 in.-oz) imbalance).
Jan. 16, 1962	Center of Gravity	24.9 cm (9.8 inches) on spin axis above separation plane, weight 129.9 kg (286 lbs., 5 oz).
Jan. 16, 1962	Moment of Inertia	1.7×10^8 gram-cm^2 (154.8 lbs-in. sec^2) about spin axis. 1.2×10^8 gram-cm^2 (109 lbs-in. sec^2) average about other axes.

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